

## Description

### DISTRIBUTION AND TEMPORARY STORAGE SYSTEM OF TRANSPORT UNITS

#### Invention Field

- [1] The present invention relates to the domain of automatic systems for handling and storage in support to the work in a factory.

#### Invention Background and Prior art

- [2] In the 80s and 90s, the industry in general and some sectors in particular, namely those related to fashion or consumer products, were subject to profound changes in the requirements of the market. The decrease in the average dimension of orders and respective delivery times, the increase of diversity of models and respective variants, the emergence of products configurable by the customer and the increase of the demand for quality are factors that have led companies to radically change their products and respective associated processes, namely marketing and sales, distribution and production.
- [3] Within the scope of the production process, one of the areas that has undergone the largest impact was internal logistics, i.e., warehousing, transportation and distribution of materials and components in the factory plant, from the raw material warehouses to those of finished products. The factors formerly referred to have induced an exponential increase of the number of lots to be handled, and therefore of the efforts and complexity of its management.
- [4] To respond to this challenge several logistic systems have been developed, with different levels of automation, whether for the inter-departmental logistics (between different sections), whether for the interior of the sections themselves, namely for production lines.
- [5] Focusing now on the systems for production lines, there are available on the market, transportation systems by suspension or by mat conveyor, partially or totally automated, with possibility of coupling manual or automatic storage systems and with more generic or more specific applications for certain types of industries and/or departments. As an example, reference is made to the conveyors for stitching lines of foot-wear companies, in its computerised (figure 1) and automatic versions with dynamic overhead storage (figure 2) of the Portuguese company LIREL, and the systems patented by Anzani PT 073,918 and US 6, 357,985, formed by distribution conveyor systems and feeding mechanisms to the work stations and temporary warehousing making use of gates and of the effect of gravity. More recently other systems were patented representing improvements or adaptations of the ANZANI's

system, namely US 6,704,613 and US 6,669,003. In alternative to the existing systems of mat conveyors, there are systems based on roller corridors and belts that allow the transmission of movement between them thus minimising the quantity of motor drives. In these systems the transfer of the transport units/boxes from the transport corridor to other adjacent ones or to the work stations/destination is done through the herewith identified as transference cells (transfer apparatus in US patents). Patent US 5,082,109 of Societe Interroll refers to this mechanism which is later improved US 6,581,749 and US 6,662,929 and used in different systems US 6,471,045 and US 6,230,872, the latter of UNITED PARCEL, uses the principle of transference cells to implement a stationary switching matrix over a set of movement channels, based on rollers and belts, so as to distribute packages with orders coming from only one source to a number of destinations.

- [6] LIREL's and Anzani's systems are based on the concept of distribution of work directly to the stations, avoiding the manual handling of production lots and also of machines, thus reducing the time of preparation of production lines every time the production of a different model is started. These distribution systems respond to the needs of the companies whose productive processes are characterised by production orders or lots of medium dimension and by a large diversity of models, maximising the productivity levels of the respective production lines.
- [7] With the passing of the 90s, the standards of consumption changed even further, increasing models diversity and the number of very small quantities orders, reaching, in some cases, to the extreme situation of special products, where each order corresponds to a specific product for a specific customer. This reality has an immediate consequence in the decrease of production lots, imposing, in some cases, the creation of unitary lots.
- [8] The current transport and distribution systems have proven unable to respond to this new reality, since the number of lots increases significantly and, furthermore, the working time of each lot decreases in the same proportion. These systems have the particularity of working like a roundabout or in circle, forcing the containers to return to the beginning of the conveyor system before being sent to the next work station or to make a complete turn around of the transport line. This way of operation prevents the current systems from effectively responding to the new production requirements, since they are not able to feed the work stations with the necessary cadency.
- [9] Further to what has already been referred, the coupling of storage systems, whether vertically or horizontally, constitutes a worsening of the routes done by the containers, since round trips to the warehouses are added. In the case of systems with warehouse, it becomes necessary to increase the stock per operation, so as to compensate the time spent in the moving of containers between the warehouse and the work stations.

- [10] New movement systems should have as one of their main objectives the reduction of containers movement time, either between work stations, or between the warehouse and the work stations. It has, therefore, become desirable the design of a new distribution and temporary storage system of transport units which will solve the problems indicated, namely through mechanisms of fast transfer of units between any work stations and between these and possible temporary storage systems, thus creating benefits and competitive advantages in relation to the existing systems.

### **Brief Description of the Invention**

- [11] The object of this invention is a distribution and temporary storage system of transport units (SIDAT), especially created to handle, in production lines with great speed and flexibility requirements, product lots, materials or components of work in progress. Examples of this type of lines are the production lines of companies related to fashion (clothing and foot-wear) and production lines of special products (namely assembly), for sectors such as furniture, metal-mechanics or electronics.
- [12] SIDAT, generally illustrated in figure 8a, is formed by an aggregated set of individual movement cells (CMi), arranged in form of a matrix, designated by matrix conveyor, and by an overhead storage system (SAT), which optionally may be associated to the conveyor. The CMis are motorised through the coupling to a centralised movement bus and have the ability of moving a transport unit known as container in any direction, to the adjacent CMis.
- [13] The compound movement cells (CMc) are constituted by the ranked aggregation of individual movement cells, associated univocally to one work station, with the function of feeding, warehousing and flowing the work carried out therein, complying with a set of requirements listed below.
- [14] The transfer movement cells (CMt) are CMi exclusively dedicated to the transfer operations of transport units between the CMcs, not being part of these and therefore not being associated to any work station.
- [15] The matrix conveyor may assume several configurations, according to the number of CMis that compose the CMcs and the number of CMts, as it will be described below.
- [16] The transport units together with the materials to be worked in the stations are placed on the conveyor from an entry and association position, where an association is formed between the container (univocally identified by a number and by a barcode or electronic tag, depending on the concrete applications and on the respective work conditions) and the information of the lot in question (namely the model, number of units and the respective operating routings). The work stations by which the transport unit will have to pass are defined in function of the operating routings and of the operations to be carried out in each station (depending on the machines and/or the

associated operators). A finer attribution will be accomplished by a scheduling algorithm of SIDAT which, in every moment, will deal with the availability of resources and will try to optimise a set of criteria, namely the minimisation of the waiting time for work, the routes and movements to be carried out and the changes to the posts configuration.

- [17] The movement of the transport unit from the position of association towards the work station may be carried out through the passage from CMi to CMi or by making use of the manipulator associated to the SAT (if any).
- [18] The movement of the transport units through the transport system is done by directing them to the point of entrance of CMcs (that is, of the work stations). Once there, the system uses the CMis (whose number depends on the specific configuration) to store transport units at the entrance, make them available to the operator and store them at the exit. All the movements of the transport units are automatically carried out by the system. The work stations operators dispose of a button to mark the end of the execution of operations in the transport unit that will be at the point of work, thereby notifying the system that it can send it to the next station and make the next transport unit available to the operator. The end of the operation may also be automatically marked, through a digital input (which can be driven, for instance, by the control system of a machine that is placed in the station).
- [19] In case there is no free destination station where to send a transport unit that is leaving a work station, it can be placed in the SAT (if any) until the situation is changed, SAT working as a temporary buffer, in addition to the storage capacity already existing at the work stations, through the CMis designated by 'Ex - waiting \_x\_', in one of the multiple possible configurations of which two will be seen below, in detail. Afterwards, the transport unit will be removed from the warehouse and sent to the work station to which it has been attributed to.
- [20] This procedure is carried out until all the routing operations have been carried out. The exit of the transport unit from SIDAT, usually after the accomplishment of all operations, is carried out through a position of exit and dissociation (becoming the unit free to be used again).
- [21] In relation to the patent of United Parcel US 6,230,872, which implements a packages selection system, in which a stationary cells matrix of roller conveyors and multi-directional belts directs packages to a plurality of destinations, the proposal of the present invention is distinct: the entire system is based on the so-called individual movement cells, whose movement is transmitted thereto from a centralised movement bus, constituting these the basic and obligatory unit for the construction of more elaborated movement, temporary storage and transfer systems, named in a general way as matrix conveyor; the proposed system in this invention allows dealing with multiple

sources and multiple destinations for the transport units allowing, under the control and supervision of a management program, to simultaneously handle multiple transport units following their predefined operating routings. The logic aggregation of two or more movement cells constitute the so-called compound movement cells, associated to the work stations, which possess, other than the basic movement attributes, functions of temporary storage. For the reasons presented above the components of the system proposed in the present invention are innovative and so is the system as a whole, adjusting itself to a range of applications much wider than the currently existing systems.

### **Brief Description of the Figures**

- [22] The functional and constructive features of SIDAT are better understood through the detailed presentation and explanation of the attached drawings. The represented configurations are given exclusively as way of example and do not intend to be restrictive regarding other possible configurations using the concepts and components described in this patent.
- [23] Figure 1 shows, as an example of the prior technique, a conveyor for stitching lines of foot-wear companies, in its computerised version.
- [24] Figure 2 shows, as an example of the prior art, a conveyor for stitching lines of foot-wear companies, in its automatic version with dynamic overhead storage.
- [25] Figure 3 shows a CMi under the forms of diagram (a) and 3D view (b). The transport unit movement mechanisms are pictured in the two directions and four possible orientations.
- [26] Figure 4 shows a CMc created from the ranked aggregation of four CMis. In this configuration there is one waiting position (E1) (6), one entrance and waiting position (E2) (5), one work position (T) (7) and one post-work storage position (AT) (8). The straight arrows represent the possible orientations and directions of transport units circulation, while the curved arrow represents the direction of movement of the transport unit inside the CMc.
- [27] Figure 5 shows a CMc created from the ranked aggregation of two CMis. In this case, there is only one entrance and waiting position (E1) (6) and one work position (T) (7).
- [28] Figure 6 shows the centralised movement bus that provides the means to transmit movement to the CMis mounted thereon.
- [29] Figure 7 shows the coupling mechanism of the CMis to the centralised movement bus.
- [30] Figure 8 shows a general view of the system and its versions a) with the matrix conveyor only and b) in which the matrix conveyor is complemented with an Overhead Storage System and a three-axis associated manipulator.

- [31] Figure 9 shows a SIDAT configuration formed by a matrix conveyor resulting from the ranked aggregation of CMc and by a SAT.
- [32] Figure 10 shows a SIDAT configuration formed by a conveyor resulting from the ranked aggregation of CMcs and by two CMis central corridors with the function of moving the transport units between work stations.

### Detailed Description

- [33] Referring to figure 3 (a and b) a CMi is formed by: a set of rollers (1) which, when in rotation, enable the movement of a transport unit in the rotation direction, depending the movement direction on the rotation direction; by a system of distribution belts (2) assembled over a platform which enables its elevation above the the roller system level (1) enabling, when in motion and in the upper position of the elevating platform, to move a transport unit in a direction perpendicular to that of the rollers and in the direction of the respective rotation. Depending on the movement to be carried out, the side guides/bumpers (3) will be raised by means of pneumatic cylinders and associated mechanisms (4) so as to ensure a straight and guided displacement of the transport unit and eventually its stop in the intended location. The CMi is assembled over a power driven chains/belts bus (11) to which it establishes coupling through a system described below, thus allowing the CMis rollers or chains system movement.
- [34] Referring to figure 4 , a CMc is formed by the ranked aggregation of four CMis. The four CMis will have distinct designations according to the functions that are associated thereto:
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|-----------------------------|--|
| <b>E2 - waiting 2 - (5)</b> | cell that receives the transport unit coming from another CMc or from the SAT's manipulator, being the next step its placement at E1. This cell works as a second storage buffer for the work station.   |
| <b>E1 - waiting 1 - (6)</b> | cell that works as a buffer for the work cell T1, receiving the transport units from E2.   |
| <b>T - work - (7)</b>       | cell where the contents of the transport unit are accessed by the worker so as to execute the operation which has been defined for the work station associated to the CMc.   |
| <b>AT - post work - (8)</b> | cell where the transport unit is displaced to, immediately after completion of work at T. In the event of the worker finalising work at T and the transport unit may not immediately proceed to AT, the worker may access the transport unit at E1 and start the respective operation. |
- [35] The movement of transport units between E2 and T is carried out in an automatic way by the system. The movement from T to AT is carried out after the completion of work at T, which takes place only when the worker signals such event, using an

existing pushbutton at the work station for this purpose.

- [36] Once at AT, the transport unit will proceed to a CMi E2 associated to the work station at which the next operation of the operating routing will be carried out. These movements between CMcs are managed by SIDAT's scheduling and management algorithm which, depending on various criteria, will decide when, how and where to move the transport unit.
- [37] Referring to figure 5 , a simplified compound movement cell is presented, in relation to that of figure 4, designated below as CMcs, which is formed by the ranked aggregation of two CMis, E1 and T (6, 7). The transport units movement from E1 to T is automatically carried out by the system. The movement from T to a neighbouring CMi is carried out after the completion of work in T and complying with other conditions described below in the detailed description of the configuration of the matrix conveyor illustrated in figure 10.
- [38] Referring to figure 6, the CMis are power driven by means of mechanical coupling to a movement bus formed by a distribution belts/chains system (11) connected to a set of motors (10), arranged in form of matrix so as to be able to transmit movement to all conveyor's CMis, assembled thereon. Depending on the belt to which the coupling is done, the movement of the transport unit is obtained, in the desired direction and orientation.
- [39] Referring to figure 7, the movement transmission mechanism to the rollers (1) and CMis belts through the centralised movement bus is carried out by means of a pneumatic actuator (12), a coupling system (13) and a chain or notched belt (11). In figure 7 a ) , with the pneumatic actuator distended, the coupling system does not make contact with the belt/chain and the rollers/belts are stopped. At a second moment, figure 7 b), with the retraction (15) of the pneumatic actuator, the coupling system establishes contact (16) with the belt/chain thereby transmitting movement to Cmi's rollers or belts system.
- [40] Referring to figure 8 a , an overhead movement and storage system (SAT) of transport units will serve as a temporary buffer between work stations for the transport units. The SAT is constituted by a set of overhead storage cells (CAT) (22), organised in form of a matrix, in which a transport unit may be placed or removed by the associated manipulator (17). The latter will allow the movement of transport units (16) between CMis (15) and between these and the CATs. When stored in the CATs the transport units will stay placed over the conveyor at a higher level, i.e. in the 'overhead' (hence its designation), obviously observing safety standards through the placement of a protection structure (23).
- [41] There are three working levels for the manipulator: a first one at the work stations level (20), a second one, further above, where the manipulator moves the transport

units between CMis (18) and, lastly, a storage level (19). Below the work level there is a zone reserved to the centralised movement bus (21).

- [42] The retention mechanism (24) of the transport unit in the CAT is purely mechanic and its design is modular, similar to the CMis. Therefore, if a CAT gets damaged, it will be marked as unavailable in the management system, and its maintenance will be carried out without the need for the SIDAT system to be shut down. In figure 8 the SAT is illustrated with the manipulator and the CATs, with its details not constituting restrictions as to its possible distinct practical implementations.
- [43] Referring to figures 8a and 9, a possible configuration of SIDAT is formed by the ranked aggregation of CMcs (25) arranged according to the figure, and by a SAT. The SAT is set up over the central channels of the conveyor (28) formed by the CMis E2 and AT.
- [44] The transport units are placed in the conveyor from an association position (26). The work stations (9) through which they will have to pass are defined by the system, in function of its respective operating routings and of the station able to perform these operations; a finer attribution will be accomplished by a management and scheduling algorithm of SIDAT which, in every moment, will deal with resources availability and will try to optimise a set of criteria, namely the minimisation of time waiting for work, the minimisation of blockages in the CMcs, i.e., when a transport unit finishes the work and is unable to be immediately sent to another cell, etc.
- [45] The movement of the transport unit from the association position (26) towards the CMc (25) associated to a work station (9) may be carried out through the passages of the adjacent CMcs, in front or at its right, or else making use of the manipulator associated to the overhead storage system, in the cases in which the CMc associated to the next indicated work station in the operating routing is another one.
- [46] After arrival to the cell E2, the transport unit will proceed automatically to E1 and from there to T everytime that they are available, i.e., without a transport unit. Once the transport unit is placed at cell T, the worker will take the materials out of the transport unit and will carry out the operation(s) intended to be carried out at his or her work station. After completion of the work programmed for this work station, the operator will signal the system through a pushbutton and the transport unit will automatically proceed to the cell AT, in case it is free, or directly to cell E1 of the neighbouring CMc, in case this is the next work station of the transport unit and the respective cell E1 is free. After the placement of the transport unit in AT, in case there is no immediate availability of the necessary resources, namely a free destination station or SAT manipulator is carrying out other movements, the transport unit may, at first instance, wait until the situation changes, since, in the worse case, work has just started at this point in the next transport unit. The execution time of the transport unit



operation at T corresponds to the time interval the transport unit in AT has to proceed to the next work station or to the SAT without causing a blockage in the exit from T to AT. The possibility is added to extend the acceptable permanence period of a transport unit at AT, since the worker at the work station will be able, in this configuration, to access the transport unit contents at E1, thus being able to continue the work without interruptions. SIDAT's management and scheduling algorithm will deal, in every moment, with the need of optimising the resources so as to avoid these blockage situations and, simultaneously, try to optimise the work station occupation, ideally at 100%.

- [47] SAT works as a temporary buffer, in addition to the buffers already implemented in this configuration with the CMs 'E1 - waiting 1', 'E2 - waiting 2' and 'AT - Post Work', constituent parts of the CMc. The manipulator associated to SAT will carry out all movements from CMc to CMc that occurs in non-adjacent cells and additionally those movements that force making a course contrary to the normal working flow in this configuration. In case a transport unit is at AT and there are no available station (cell E2 free) able to carry out the next programmed operation of the operating routing, the transport unit can proceed to SAT, to a free CAT that is preferably near the next work station and associated CMc; The situations of inadequate flow balancing are compensated through an increased storage capacity at the work stations complemented by the SAT.
- [48] In this configuration, the CMcs have autonomy to carry out the movements from E2 to AT, becoming possible that a very large number of movements from CMi to CMi may occur simultaneously in the core of CMcs. Likewise, several translation movements of transport units may occur simultaneously between adjacent CMcs.
- [49] The exit of the transport unit from SIDAT, normally after carrying out the totality of the operations, is accomplished through a dissociation position (27).
- [50] Referring to figure 10, an alternative configuration for SIDAT will be formed by the ranked aggregation of CMcs (28), arranged according to the figure, and by a set of CMts (29), disposed in form of central corridors, with the function of moving transport units between CMcs. In this configuration the association of a SAT is optional.
- [51] A transport unit containing a production lot to be processed at the work stations served by the matrix conveyor is associated to the SIDAT through an association position, existing two such positions in this configuration, proceeding afterwards to the CMc associated to the work station where the next programmed operation will be performed. The movement of the transport unit is carried out through the passage between CMts, which form the central corridors of the matrix conveyor, towards cell E1, which must obligatorily be free.
- [52] After the arrival to cell E1 the transport unit will automatically proceed to T

everytime it is available, i.e., without a transport unit. Once the transport unit is placed at cell T, the worker will remove the materials from the transport unit and will execute the operation(s) programmed to be carried out in his or her work station. After completion of work, the operator will signal to the system through a pushbutton or alternatively the SIDAT management will issue that order in the end of the time period programmed for the operation in question. The transport unit will proceed afterwards to cell E1 of the next work station through one of two possible ways: 1- if the next programmed work station is the adjacent one and cell E1 is free the transport unit will pass directly. 2- through the CMts cells, as soon as the route designed over the CMts and decided by SIDAT's scheduling algorithm, is partially or totally free.

[53] After the signalling of the end of operation, the transport unit may, due to unavailability of a CMt route, or alternatively due to a manipulator associated to SAT being busy (if any), stay at cell T. Such situation is possible since the worker at the work station will, in this configuration, be able to access the contents of the transport unit at E1, thus being able to continue the work without interruptions. SIDAT's management and scheduling algorithm will deal, in every moment, with the need of optimising the resources so as to avoid these blockage situations managing the CMts functioning, through the partial allocation of resources and the possibility of multiple movements with distinct extensions and orientations and, simultaneously, trying to optimise the work station occupation, ideally at 100%.

[54] The CMcs have a buffering capacity inferior to that of CMcs having only one waiting position; this configuration has nevertheless the advantage of being able to send transport units to previous work stations, i.e., in the opposite direction to the normal flow of the operating routing, thus being able to function without SAT and the associated manipulator.

[55] Besides the preferential configurations presented in figures 8, 9 and 10 there are, however, a set of others whose usage may occur in a short period of time and whose structure is briefly described, since its functioning principle is identical to the two preferential configurations above described in detail:

- Two CMcs lines placed side by side so as to function as a circular movement structure.
- Two CMcs lines with a CMt central channel instead of the two existing ones in the preferential configuration of figure 10.
- Two CMcs lines with two CMt central channels, so as to avoid the obligatory presence of an overhead storage system in the preferential configuration of figures 8 and 9.
- Two CMcs lines with 3 CMt central channels, so as to increase the cadency of the configuration presented in the previous paragraph.

[56] SIDAT's management system based on a PC and/or a programmable logic controller is based on an information organisation model for which it is defined, firstly, the operating routing structure, necessary to produce a certain article and, after that, which resources and information are necessary to the correct execution of those operations. The system is composed of several modules, listed below, in order to be able to work isolated or integrated with ERPs or other enterprise management systems:

- A configuration module of engineering information associated to products, resources and information necessary to the operations execution (machines, people, tools, raw material, operating routings, etc).
- A preparation module of the manufacturing orders and other associated information lots.
- A configuration module of the matrix conveyor and of the Overhead Storage System.
- A control module of the matrix conveyor and of the SAT associated manipulator.
- A work scheduling module in SIDAT, associated to a multi-criteria optimisation algorithm, for the determination of the movements to be carried out at every moment.
- A monitoring and historic information module.
- Interfaces of integration with ERP systems or other management systems.